DEVELOPING SOUNDS FOR A MULTIMODAL INTERFACE: CONVEYING SPATIAL INFORMATION TO VISUALLY IMPAIRED WEB USERS

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ABSTRACT

A multimodal browser plug-in, with audio and haptic feedback, has been developed to explore how basic concepts in spatial navigation can be conveyed to web users with visual impairments. In this paper, the second version of an audio interface for this plug-in is described in terms of its development and integration with haptic feedback. This version of the system was evaluated within a collaborative setting, in order to investigate whether it is possible to use this tool in a working environment between visually impaired and sighted Internet users. The auditory interface is discussed based on user feedback from this evaluation, and future sound design plans are presented in relation to the new direction for the overall system.

[Keywords: Sound Design, Multimodal Interface, Web Accessibility, Visually Impaired Users, Collaboration]

1. INTRODUCTION

The development and popularity of visual Internet browsing applications has meant that the main information content for the Web is designed for the benefit of sighted users. For users accessing web pages through a non-visual medium such as a screen reader, web browsing has become a much more challenging process. Despite developments in screen reading technologies and web accessibility guidelines, visually impaired Internet users experience significant problems accessing information online in comparison to their sighted counterparts.

This paper describes an attempt to bridge the gap between assistive screen reading technologies and mainstream visual Internet browsers, by providing an alternative approach to web exploration for visually impaired users. A web plug-in with audio and haptic feedback has been developed in an attempt to fulfil this objective. The initial designs and further development of sounds for this interface, and integration with haptic feedback are presented in this paper. This auditory interface prototype has been evaluated as a collaborative tool to enable understanding and communication between visually impaired and sighted Internet users. This evaluation is presented and future directions for the auditory interface and overall system are discussed based on the results of this experiment.

At an early stage in this present study, a comprehensive requirements capture with thirty visually impaired participants, was conducted to determine specific problems that visually impaired screen reader users encounter when accessing the Internet [1]. Analysis of data from this survey has revealed two major areas that current assistive technologies do not adequately address; firstly in developing an awareness of web page layout and secondly in relation to navigational guidance. Screen reading technologies provide speech feedback to the user in a linear format. Therefore it is not possible to gain an understanding of the spatial layout of a web page using this technology. Visually impaired Internet users interviewed as part of this study felt an awareness of spatial information would enhance their experience on the Web by improving collaboration with sighted users. Furthermore the possibility of perceiving the layout of web objects on a page would benefit visually impaired web developers so that they can control the placement, size and layout of objects on a web page. With a view to addressing these issues, an assistive web plug-in has been developed to convey spatial information through a multi-modal interface with audio and haptic feedback.

Speech synthesis is most commonly used by current assistive commercial technologies for the Web. However, non-speech audio, auditory icons [2] and earcons [3] have also proved to be an effective mode to convey information in non-visual interfaces. Previous approaches at creating non-visual auditory web browsers have focused on 3D audio spatialisation techniques to convey Web document structure [4, 5]. James [6] has implemented a mixture of auditory icons with musical cues and speech processing in the AHA Browser, to convey web page structures and visual formatting. Other studies have investigated ways of conveying link structures in non-visual interfaces to parse extraneous information [7] and also to convey the visual representation of a link through sound [8]. Similarly attempts have been made to convey image information through an auditory interface using audio filtering techniques [9].

There have been various attempts to convey spatial information through non-visual interfaces. Mynatt et al. [10] have investigated the process of translating a graphical user interface into a non-visual medium for visually impaired users. WebSound [11] is a sonification tool where sonic objects are associated with HTML tags, which are then projected into a virtual 3D sound space according to finger position on a tactile touch screen. Research has also examined the use of non-speech feedback to convey spatial information in real-world spaces such as building layout [12] and maps [13].

principles for co-operative interfaces for the blind. A number of tools have recently been developed to enable visually impaired and sighted users to explore the same virtual environments through different modalities [16, 17, 18]. Salnass et al. [18] have investigated how sighted and visually impaired users interact in shared virtual environments, when asked to perform a series of collaborative tasks involving navigation and spatial orientation. Many multimodal collaborative tools have focused upon the development of haptic technologies to convey spatial cues to the user. While these current solutions include some auditory cues, it is considered that there is potential for a stronger presence of non-speech sounds to convey spatial information using a multimodal interface.

In the following sections the multimodal web plug-in is described in detail before discussing the use of the plug-in in a collaborative setting.

2. THE AUDITORY INTERFACE

This auditory interface was designed as part of the larger multimodal browser plug-in. In this paper, the development of the auditory interface is described from the original design method to implementation in the system. Haptic feedback is also presented in relation to its integration with the auditory cues.

2.1. Multimodal Web Plug-in Description

A detailed description of the overall system design can be found in our previous report [19]. The haptic effects are provided via a Logitech Wingman force-feedback mouse. Non-speech audio feedback has been designed and played back in Pure Data, a real-time audio programming environment. Speech is provided via the development of a plug-in utilising the Microsoft Speech SDK. All of the

Sound designers have different preferences for the use of auditory icons based on environmental sounds or musical earcons to convey information. Comparative studies have revealed that the reaction time for auditory icons is shorter than for earcons in multimedia interfaces but earcons can convey more complex information, while repetitive auditory icons can cause irritation for users [22]. A number of auditory interface designers have chosen to convey information through musical sound rather than environmental or abstract sounds. For example Vickers and Alty [23] have investigated how complex information structures can be conveyed through purely musical structures.

The sounds designed for the interface in this present study are based on a mixture of auditory icons and earcons.

Currently there is a growing body of work investigating the relationship and differences between visually impaired and sighted computer users. Goble et al. [14] attempted to build a framework of web-navigation based on models of real world travel by both sighted and visually impaired users. In this study, travel objects are presented as either cues or obstacles i.e. an image on a web page is identified as a cue for a sighted person but as an obstacle for a visually impaired user. Winberg et al. [15] highlighted the lack of investigation in computer-supported co-operative work for blind and visually impaired users in a study that reconsiders design components are co-ordinated via a Firefox extension, which parses and analyses the webpage, then sends the information to the audio and haptic devices.

When a web page loads, the absolute position of each HTML element is calculated, along with relevant information, such as the element height and width. A semantic value is also determined for each element – for example, for images the alt attribute value is used. As the user moves the mouse, the relative position of each element in relation to the mouse cursor is calculated. This enables the HTML element nearest to the mouse cursor to be determined. If the mouse cursor is in the vicinity of the element (defined as being within 50 pixels), the user is given feedback as to the position of the element in relation to the cursor. As the cursor actually moves over the element, additional feedback is presented to the user.

2.2. Sound Design

The sounds designed for the web plug-in are intended to provide the user with a sense of navigation in relation to the spatial layout of web objects on the page. Sounds for this interface were designed using a semiotic design method based on a scenario in a radio-play format presented to a panel to trigger original creative ideas. This design method (presented and discussed in full in [20, 21]) involves three independent and consecutive design panels where participants brainstorm sound effects for a use scenario in the form of a radio-play. The method was applied to this interface to trigger creativity and to achieve a certain amount of group confirmation rather than basing all of the design decisions on the preference of one designer. The initial sound ideas for this second interface are based on the ideas developed during three user panels, described in detail in [21]. These ideas were further developed and integrated into the multimodal browser by synthesising dynamic versions of the sounds in Pure Data.

2.2.1. Environmental Vs Musical Earcons

Some of the sounds designed for this interface cannot be separated into entirely environmental or entirely musical origin, but have been developed using both metaphor and encoded musical techniques. Purely musical approaches to auditory interface design can be difficult for users if they are based on users decoding concepts related to musicianship or musical theory. The aim of this approach is to utilise musical experience and knowledge and encode these ideas into the interface to form intuitive designs. Therefore the interface contains a mixture of environmental sounds, and abstract synthesised sounds with musical ideas and parameters applied to support their meaning.

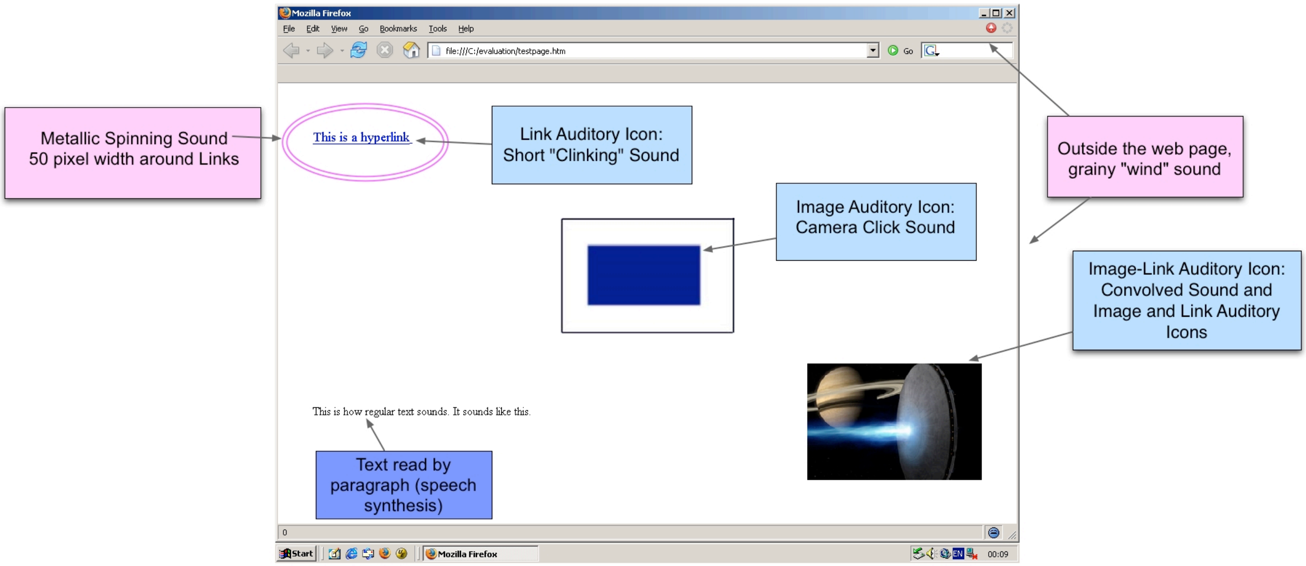

Figure 1. Auditory Interface Description (Screenshot from Training Task)

2.3. Auditory Design and Integration with Haptic Feedback

The second version of the auditory interface for the system is described in the following paragraphs. Some of the object cues remain the same as the first prototype however the navigation cues have been redesigned based on comments from the first user evaluation. An overview of the auditory cues is illustrated in Figure 1.

2.3.1. Object information feedback

As the user rolls over an image or a link with the force-feedback mouse, an auditory icon is played to reinforce a haptic response. In this system, the auditory icon that indicates an image is a short descriptive sound clip of a camera shutter clicking, suggesting a photograph or graphic. With the force-feedback mouse, the user is able to perceive the boundaries of the image, using an *enclosure effect* coupled with stiff walls. Upon mounting and rolling over the image, a *periodic effect* has been produced, heightening the sense of positional awareness when moving from the border to the body of an image.

The auditory icon used to depict a link is a short "metallic clinking" sound. In terms of haptics, hyperlinks have been represented using spring effects, attracting the user to the vertical centre of each element, where the user can select the link without falling off the target. The hyperlinks have been coupled with a distinctive wave effect. The auditory icon to depict an image-link was creating by convolving the two link and image sound icons together to create a sound that resembled the camera click with a metallic timbre. The haptic feedback attracts the cursor to the centre point of an attractive basin using a spring effect, where the mouse can be clicked without deviating from the targeted image-link.

2.3.2. Locational Cue

In the previous version of the system, the relative distance from the cursor location to the image or link was mapped to panning (left to right as the user moves the cursor along the x-axis) and pitch-shift parameters of a continuous background sound (frequency changes according to the y-axis cursor position). However the first evaluation of this interface with visually impaired users revealed that users were utilising this cue as a 'block aura' around links and images, without using the pan and pitch feedback to locate the object position relative to the cursor location. Some users perceived the location cue but found it difficult to move the force-feedback mouse in response to the subtle changes in panning and pitch.

This locational sound was entirely redesigned for the next version of the interface. The original idea for this sound was based on discussion in a participatory user design panel described in detail in [21]. Navigation towards links was considered one of the most important cues involved perceiving the spatial layout of the web page. Users were more interested in locating links (plain text or image-links) as they provided the navigation path for the site. Rather than mapping the spatial distances around links directly to the pan and pitch parameters of an abstract sound, a new sound was created based on ideas from a design panel discussion [21].

One participant in a design panel suggested using the metaphor of the sound of a falling lid, imitating the accelerating rhythm of a round object, spinning on a flat surface to convey the idea of being pulled into a location point through sound. This idea was implemented as a static sound for the purpose of the iterative design method used [20] and then finally implemented as a dynamic version in PureData (PD) as part of the assistive web interface. *Netreceive*, a PD external object is used to receive web-object information and x and y location co-ordinates sent via UDP from the web plug-in (Figure 2). A sound was synthesised, with a swirling metallic-plate-like timbre. This sound increases in intensity and rhythm as the cursor draws closer to the link. The original horizontal mapping of x value cursor movements to left to right panning was maintained in this new sound design. So that when a user is within 50 pixels of the link, they will hear a fainter slow swirling sound, panning left to right with the cursor movement, which becomes more intense until they hover over the link. Once positioned over the link, they will hear the link auditory icon (and link text) to confirm their position. The cue is intended to work like a virtual sonar effect. Furthermore, it was intended that this auditory cue would complement the haptic spring effect that pulls users towards the centre of the link.

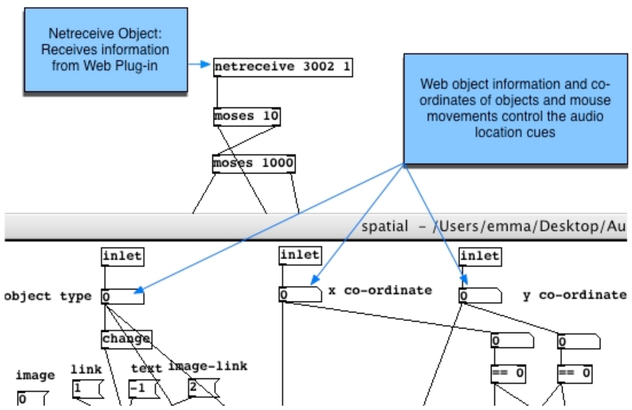

Figure 2. Receiving and manipulating web object information in PD.

2.3.3. *Web Page Boundary Cue*

Feedback from the first evaluation of the interface indicated that users needed a more effective cue to determine that they had left the web page [19]. In the previous version of the interface, this was conveyed by a simple auditory icon, which repeated until the user was inside the web page. For the second version of the interface, a new audio cue was created to signal that the user has left the browser window. This sound needed to be prominent to the user as it is an important audio cue to keep the cursor inside the main part of the web page. However, it could not be too intrusive as the user regularly hit off the boundary of the web page. A sound was synthesised in PD using white noise and filters to produce a gentle but distinctive audio cue. The sound was created as an environmental sound, an imitation of the wind, which also created the metaphor for "being outside" a space. The border was reinforced with a haptic *enclosure effect*, allowing the user to perceive thick walls around the main body of content. Once inside the main body of the page, the user can perceive the inner side of the walls, where force must be applied to mount the ridges to leave the interior of the page.

2.3.4. *Speech Audio*

Currently text on a web page is treated as another web object, as the user rolls over non-link text on a page, the text is read to the user by paragraph. The speech will stop when the user moves off the text onto another object. Furthermore as the user rolls over an image, alt text is read to the user while the auditory icon simultaneously informs the user that the object is an image. Similarly as the user rolls over a link, the speech synthesiser reads the text while the link auditory icon plays.

3. EVALUATION

The main aim of the previous set of evaluations, involving twelve sighted and seven visually impaired users, was to determine if visually impaired users could accurately form a mental model of a web page layout using the plug-in (these results are detailed in [19]). The evaluation revealed that although objects sizes were not completely accurate, users could successfully form a mental model of the spatial layout of the web pages.

In this present user evaluation of the system, the previous idea of testing whether users could perceive a mental model was developed further by testing the plug-in as a collaborative tool for blind and sighted Internet users. This experiment required visually impaired participants to work with a sighted user to perform a series of tasks using the multimodal interface based on a real world situation. The aim was to firstly investigate whether the interface could be used as an effective collaborative tool for blind and sighted users, and secondly to assess the benefits and weaknesses of audio and haptic feedback during page exploration. This collaborative evaluation experiment was part of a wider set of tests [23]. In this paper the main focus is on users' responses to auditory feedback.

3.1. Experiment Design

Fourteen visually impaired users aged between 18 and 65 with levels of sight ranging from low vision to complete occlusion volunteered for the study. Seven participants had a congenital visual impairment and seven had lost their sight later in life. All participants were screen reader users. Two of the fourteen had no previous experience of using the Internet, but had expressed an interest in learning how to interact with the Web.

Before beginning the main task, all participants were provided with up to fifteen minutes on a training page (Figure 1) exposing them to the multimodal cues. All cues representing elements on a web page were introduced unimodally (haptics followed by audio) to help users with learning and retention of multimodal feedback. Each audio cue was presented separately to the user and they were asked to attempt to decode and understand the meanings before the audio cues were fully explained.

3.2. Evaluation Procedure

Participants were presented with a real-world scenario of working with a sighted user to attain a common goal on a web page. As part of this scenario, participants were asked to perform a series of six steps to download an Internet installer plug-in, by navigating seven consecutive linked web pages with the help of a sighted user.

The task required each visually impaired participant to explore a web page searching for a certain section of text or particular element (landmark), suggested by the sighted user who was playing the role of a telephone-based customer services advisor. The sighted user could only communicate in terms of spatial directions in respect to web objects e.g. "search for the hyperlink "next', it's to the right of the "installer" image located below the text". All six navigation screens contained the same basic layout throughout but the centre section containing links, images, image-links and text, was different.

Starting at the left-hand corner of the page, the participant was asked to locate a hyperlink or image-hyperlink within the page. This target would enable the user to move to the following page. Before being given the details of the target that they had to locate, users were asked to explore the page to gain an overview of the objects present. If participants were content to keep browsing, they could spend up to ten minutes per page. Participants were encouraged to communicate, using spatial descriptions with the sighted user if they were unsure of their location on the page.

3.3. Experiment Results

3.3.1. Using the Plug-in as a Collaborative Tool

All users completed the task within the imposed time constraints, taking an average of 61 seconds on each screen to locate and select each target. After completing the first screen, users generally became faster at navigating the interface revealing that they were retaining a mental model of the spatial layout of the web page.

Users were comfortable communicating with the sighted user, and receiving spatial directions during the task. Participants tended to describe their position using object positions rather than spatial descriptions and receive directions from that particular location. For example one participant was able to communicate with the sighted user to inform them which object he was on to process spatial directions from that point.

Example from transcript based on the screen in Figure 3:
Sighted User: From NTL logo, move right and move down to locate the text
Sighted User: Where are you?
Visually Impaired Participant: At the Broadband installer image
Sighted User: Move right slowly
Sighted User: Where are you?
Visually Impaired Participant: Digital TV link
Sighted User: Cable link is to the left of Digital TV link and to the right of Broadband installer image
Visually Impaired Participant: I've located the link

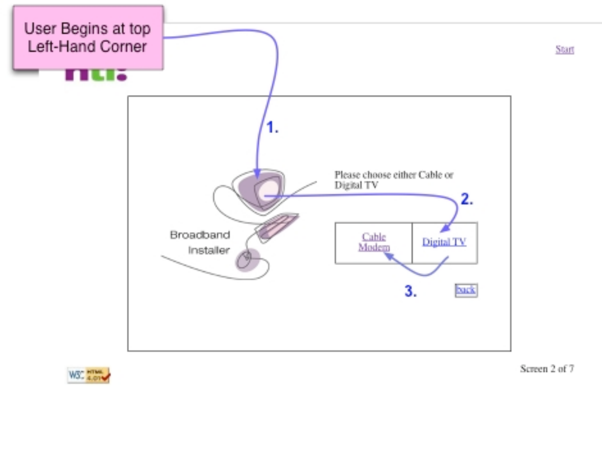

Figure 3. Direction Path for User

When the same user was asked to give a description of the spatial positioning of objects on the page after the task was completed, he correctly identified the location of objects on the web page. It seemed that he had formed a mental model of the spatial layout but found it difficult to communicate this during the task. Although most users were confident receiving and communicating with spatial directions using the interface, there were times when they became overloaded trying to understand verbal directions while processing the sounds that they heard as they navigated the web page.

It was interesting to observe that participants used objects on the page as landmarks to develop routes to access their destination, similar to the way that landmarks and cues are used in real-world mobility training. When participants encountered a link or image that was not a target, they used both audio and haptic feedback from these objects as paths to finally locate the intended targets. The locational cue around links was particularly useful for this as when the user heard the beginning of the "swirling" sound they knew that they were getting close to a link object but did not need to roll over the object to confirm that it was there. In Goble et al.'s [14] framework of web-navigation referred to previously, an image on a web page was labelled as a cue for a sighted person but an obstacle for a visually impaired user. However in these evaluation results, users were perceiving images as cues rather than obstacles when using the web plug-in, as they were able to trace the boundaries with audio and haptic feedback to form paths around the page.

3.3.2. Users' Response to Audio Feedback

All participants were able to associate the auditory icons with the elements they were intended to represent. Similar to the previous evaluation, the camera click sound was found to be particularly effective, enabling participants to visualize a photograph. In some cases, the auditory icon representing a hyperlink was overshadowed by the locational cue surrounding each link. Participants suggested an increase in the dynamic range between the link auditory icon and the locational cue to make the link auditory icon more prominent.

The swirling locational cue itself was found to direct participants to the correct area of interest, and was rated highly by thirteen participants. Post-task questionnaires revealed that users rated this cue highly as it was effective in identifying navigational links (Figure 4).

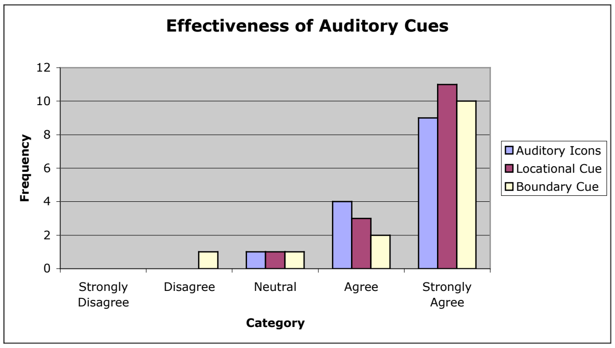

Figure 4. Effectiveness of Auditory Cues

Users experienced some confusion with the auditory icon designed to represent an image-link. During the familiarisation task, only a few users recognised that the auditory icon was a mixture of the sound used to convey a link and an image. They did not associate the sound as a concurrent playback of the previous image and link icons but identified it as a new auditory icon. Some of the confusion could be attributed to the fact that most users were not familiar with the concept of an image-link. Also studies have recommended using a 300ms onset delay to separate sound sources for both concurrent earcons [25] and auditory icons [26]. Furthermore, Brazil et al. [26] found that similar object and action descriptors for auditory icons could decrease rates of identification. This will be a consideration in the design of feedback for future versions of the auditory interface.

Users found the auditory boundary cue helpful, and most commented that it supported the corresponding haptic effect. However one user advocated that this cue should provide more detailed information of where the cursor is off the page. Currently the feedback is designed so that it is “on/off” depending on whether the user is in or out of the boundary of the web page. Future implementations will include more information on how close to the boundary the user by shifting the intensity of the sound according to the mouse position.

Although users worked well using both haptic and audio feedback navigating and understanding spatial layout, the first screen posed more of a challenge to users as it took longer to form an idea or map of the placement of web objects. Participants generally spent a longer period of time exploring and locating the target on the first screen of the first task they were given (158 seconds), compared with the last screen within the same task (45 seconds). The exploration time was much longer on the first screen as users had not yet formed a mental representation of the constant objects that were contained on each page.

4. LESSONS LEARNED: A NEED FOR AN OVERVIEW

The individual auditory cues designed for this interface were generally rated highly by participants in the evaluation discussed above. Participants were able to successfully develop a mental model of the page layout through the use of feedback. This made navigating similar web pages easier as they already had a mental representation. However, the timings were slow for all users on the first screen of the sequence showing that the browser is more time consuming on unfamiliar pages. It is hypothesised from observations of the users during exploration of the page that they could benefit from more information on less familiar pages. Furthermore, the use of an overview in a collaborative task could prevent the overload that occurred when users tried to understand verbal directions while trying to navigate with the interface. The validity of providing an overview to the user does not need to be defended here. The idea of generating an overview before navigation conforms to Shneiderman’s [27] information seeking theory. Decisions about what information should be conveyed best through the audio or haptic modalities form an integral part of the design of the multimodal system. It is considered for this system that summary and web object information would be best conveyed through the auditory modality. Furthermore there is a strong body of literature that supports the use of non-speech sound to convey overview information [28, 29].

The multimodal system was originally designed to convey spatial information to visually impaired users, as this information is not received through a conventional screen reader. From the outset, the idea was to first investigate navigation issues exploring the layout of the page and placement of objects. However, analysis of the last two major evaluations, have revealed that an auditory overview is necessary and almost a pre-requisite for this type of spatial navigation. During the first user evaluation experiment users recommended a summary of page attributes and objects, and also the spatial positioning of objects to be presented when the user arrives on a Web page. Users could then gain an understanding an overview of content of what is on the web page before they begin to navigate.

In terms of overall system development, a grid extension [30] to the system is currently being developed which will provide the user with more precise locational cues. Currently, this system is speech-based but it is hoped that non-speech sounds in the form of cell overviews will enhance the system. The sounds designed for this sonic web-page overview will be based on the design methodology [20] specifically to be integrated with the audio interface for the multimodal plug-in. However a non-speech overview of content on a web page, including layout information could also be a useful stand-alone tool or a valuable addition to a screen reading tool.

5. CONCLUSION

An auditory interface for a multimodal tool to enhance the web page browsing experiences of visually impaired users has been designed and evaluated in a collaborative environment. Using the multimodal cues, users were able to successfully navigate a sequence of screens with directions from a sighted user. The task chosen for the evaluation was chosen to reflect a real-world scenario of a visually impaired user interacting with a sighted telephone-based advisor. It is hoped that future versions of the system can be evaluated using a scenario that reflects a more balanced set of tasks in terms of both users giving and receiving spatial directions. An idea for such a task would be to test the system with a web page design task between a sighted and visually impaired user.

Originally, the main aim of the system was to convey basic spatial information to a visually impaired user. However, in the process of developing the auditory interface, it has become apparent that it is necessary for the user to always have an idea of the macro view of web page layout. Therefore, the next stage in the auditory design for this system will be to provide a sonified overview of web objects and their placement on a web page.

6. ACKNOWLEDGMENTS

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